

Final Report

Performance Period: 05/01/2004 – 10/31/2008

AFOSR Contract #: FA9550-04-1-0340

Instrumentation for Research and Research-Related Education on the Fabrication of Advanced Optical Fibers for DoD-relevant Research

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE (DD-MM-YYYY) 29SEPT 2009		2. REPORT TYPE Final		3. DATES COVERED (From - To) 01MAY 2004 - 31OCT 2009	
4. TITLE AND SUBTITLE (DURIP FY04) INSTRUMENTATION FOR RESEARCH AND RESEARCH-RELATED EDUCATION ON THE FABRICATION OF ADVANCED OPTICAL FIBERS FOR DOD-RELEVANT RESEARCH				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER FA9550-04-1-0340	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) RAVI K. JAIN UNIV OF NEW MEXICO - CENTER FOR HIGH TECH MATERIALS				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) GLORIA CORDOVA, ADMINISTATOR DIVISION OF SPONSORED PROJECT SERVICES - UNIV OF NEW MEXICO 1700 LOMAS NE SUITE 2200, MSC05-3370, ALBUQUERQUE, NM 87131				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AF OFFICE OF SCIENTIFIC RESEARCH 875 NORTH RANDOLPH STREET ROOM 3112 ARLINGTON VA 22203				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT UNLIMITED					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT The proposed research instrumentation will allow for greatly enhanced scope and efficiency of the ongoing programs, which have many important Air Force applications. The objective of this research instrumentation is to provide for the enhancement and augmentation of ongoing research in the area of. Research instrumentation will be procured to enhance and augment ongoing programs in optical fiber device research. The funding will allow purchase of a components for an optical fiber draw tower, which will allow growth of novel optical fibers for high power lasers and numerous other novel optical devices and systems, including micro-structured and polarization maintaining double clad fibers.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON RAVI K. JAIN
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (Include area code) 505-272-7842

Objectives

To develop a fiber fabrication facility -- based on a state-of-the-art draw tower -- that will enable the fabrication of advanced microstructured fibers. Our initial focus will be to fabricate fibers that will lead to single-polarization, single-transverse-mode, robust, narrow-bandwidth kilowatt-level fiber lasers that are highly manufacturable and easy to incorporate in various beam combination designs, while meeting the following specifications:

- Single-mode outputs with M^2 better than 1.05
- Single-mode polarization with polarization extinction ratio better than 20 dB
- Output linewidths less than 5 GHz to minimize SBS problems during high-power scaling
- Electrical-to-optical conversion efficiencies of better than 25%, with a goal of extending it towards the 40% limit in long term

Work performed under this DURIP grant

In December 2007 we received all the components for the fiber draw tower from Photonium in Finland. In June 2008, major installation was finished and test runs were performed by Photonium field engineers. Engineers in CHTM/UNM have successfully demonstrated drawing of 125 micron diameter fibers of several hundred meters length with conventional silica fiber preforms. We have designed and fabricated a microstructured fiber preform for an endlessly single mode fiber and a fixture to provide overpressure in the holes of the preform during fiber draw, and a water cooling system to hold this fixture. Preliminary testing has been completed.

Plans for use of this DURIP research and research-related educational facility

We are planning research and educational programs over the next few years in the following key areas:

- Design and development of innovative fabrication techniques of air-core holey fiber technology and use it to precisely define the refractive index at any point in the fiber.
- Design and development of low bend loss fibers (which are problematic when the fiber is designed with a particularly low NA in order to increase the mode area) by using innovative concept of tilted index profile in the cladding
- Design and development of polarization maintaining LMA structures that involve adding innovative anisotropic stress-inducing structures and related dopants to the double-clad (DC) fiber preform followed by very careful control of the fiber draw process.
- Design and development of novel asymmetric cladding-core geometries, index profiles and filtering techniques to control effects which degrade power, mode and polarization performance at high intensity.
- Design and development of novel fiber coating materials transparent to UV-radiation for fabrication of FBGs and LPGs.

Our targets for making efficient and rugged fiber lasers will involve radical new design implementations that will incorporate consideration of the following fiber design issues:

- LMA core design issues for power scaling and control of detrimental effects due to optical nonlinearities
- Incorporation of glass rods containing rare-earth and other dopants for control of refractive index, stress-induced birefringence, and photosensitivity

- Double-clad fiber designs that will allow optimum pump coupling, absorption efficiency, and optimization of gain and optical conversion efficiency, while facilitating writing of FBGs in photosensitive cores
- Novel transverse fiber geometries for control of birefringence and polarization control

A complete and successful cutting-edge design should ideally include:

- An advanced LMA core design, enabling “single mode” areas of $>1000 \mu\text{m}^2$ with bend losses of $< 0.1 \text{ dB/m}$ (i.e. total bend losses of $< 2 \text{ dB}$ for a 20 m long fiber).
- An active element dopant profile that provides higher gain in the lowest order transverse mode (i.e. with a higher concentration of optically pumped Yb-dopant near the center of the mode).
- A large net birefringence (of the order of 5×10^{-4} or larger) to facilitate polarization maintenance.
- An inner cladding design which is not circularly symmetric, and which yields a relatively small inner-cladding-to-core area ratio (< 50), to enable efficient absorption of the pump radiation for high slope and optical-to-optical power conversion efficiencies.
- A core dopant (say Ge) that enables photosensitivity and fabrication of FBGs and LPGs (in core or cladding) directly in the gain medium used for HPFLs (high power fiber lasers).
- Offsetting of the LMA core to one side of a flat-faced inner cladding (and an easily removable polymer outer cladding of low refractive index) to enable lithography of FBGs and LPGs on such fibers.